# Vision Chips: Pervasive Eyes for the Network

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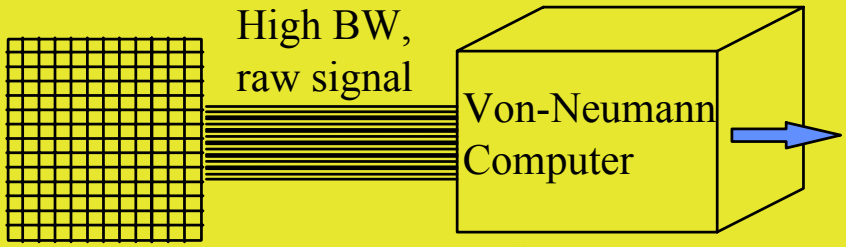
# Conventional vs. Vision Chip Machine Vision

## Conventional machine vision

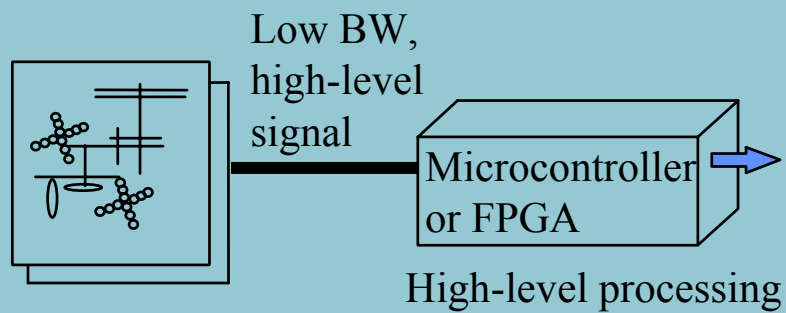



All digital processing

**Strengths:**
Off-the-shelf components
Reconfigurable

**Weaknesses:**
Large
Power Hungry
Limited by components

## "Vision Chip" machine vision

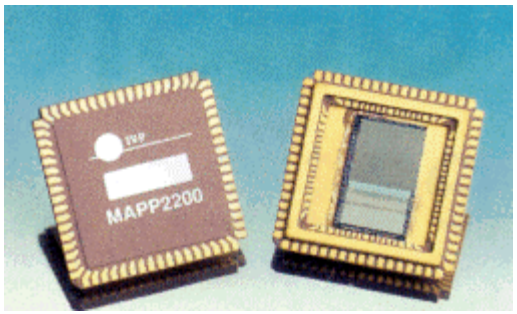


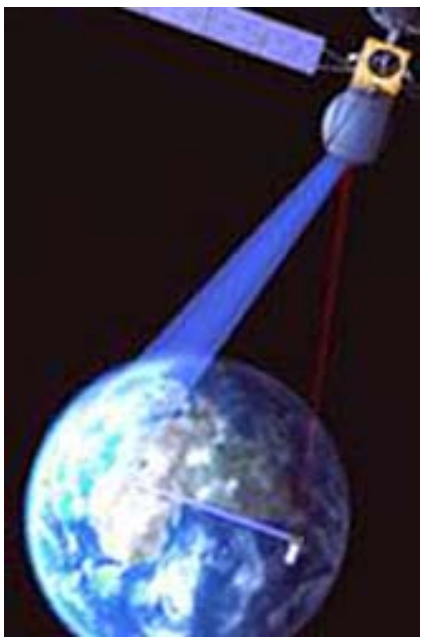

Mixed-signal (analog and digital) processing

**Strengths:**
Compact
Power Thrifty
Fast

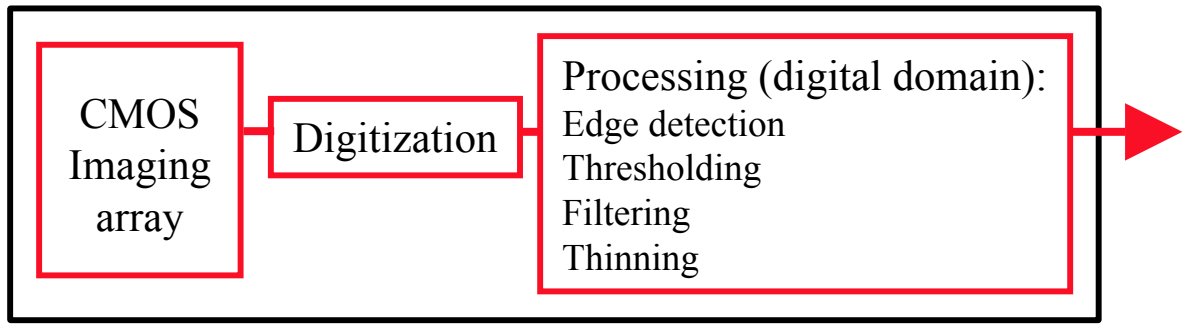
**Weakness:**
Vision chip is hardwired

# Vision Chip by *Integrated Visual Products, AB* (Sweden)



**Commercially available vision chip**



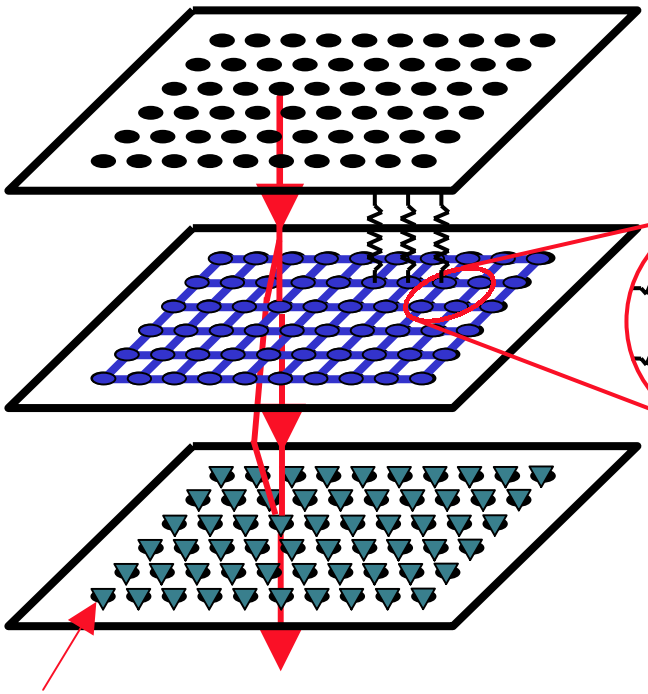

**Sample application**

Stabilization of satellite with respect to Earth using a vision chip and yaw rotation sensor

Photo credits: European Space Agency and IVP
http://telecom.esa.int/artes/artes5/fileincludes/success_stories/vision.cfm
and www.ivp.se

# Classic Silicon Retina (late 1980's)

Analog circuit for real-time contrast and edge enhancement



**Photoreceptors**
acquire raw image

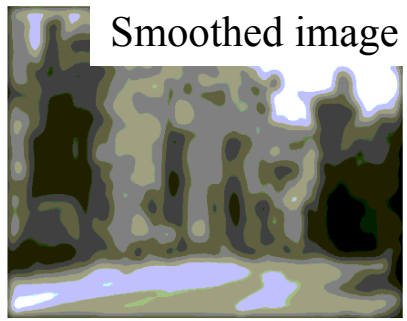
**Resistive grid**
smoothing

**Difference layer**
compute difference between raw and smoothed images

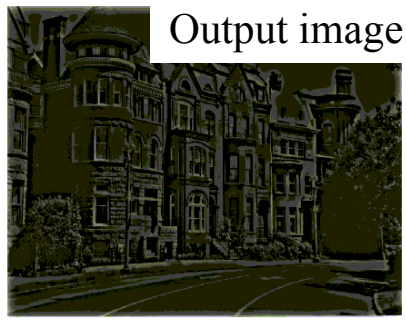
Individual differential amplifier computes difference between raw pixel and smoothed pixel

Raw image

Smoothed image (Simulated)



Output image (Simulated)



# Other Specialized Vision Chips

**Optical Mouse:** Several versions of optic mice using vision chips have appeared over the past twenty years, including the recent Intellieye™ by Microsoft Corporation
- Optically sense motion of desk (for mouse) or ball (for "trak-ball")
- Grab upwards of 10,000 frames per second
- Example of a highly successful vision chip

**Camera Focusing Sensor:** Detects "sharpness" of image for autofocusing

**Image Change Sensors:** Directly detect changes in image intensity.

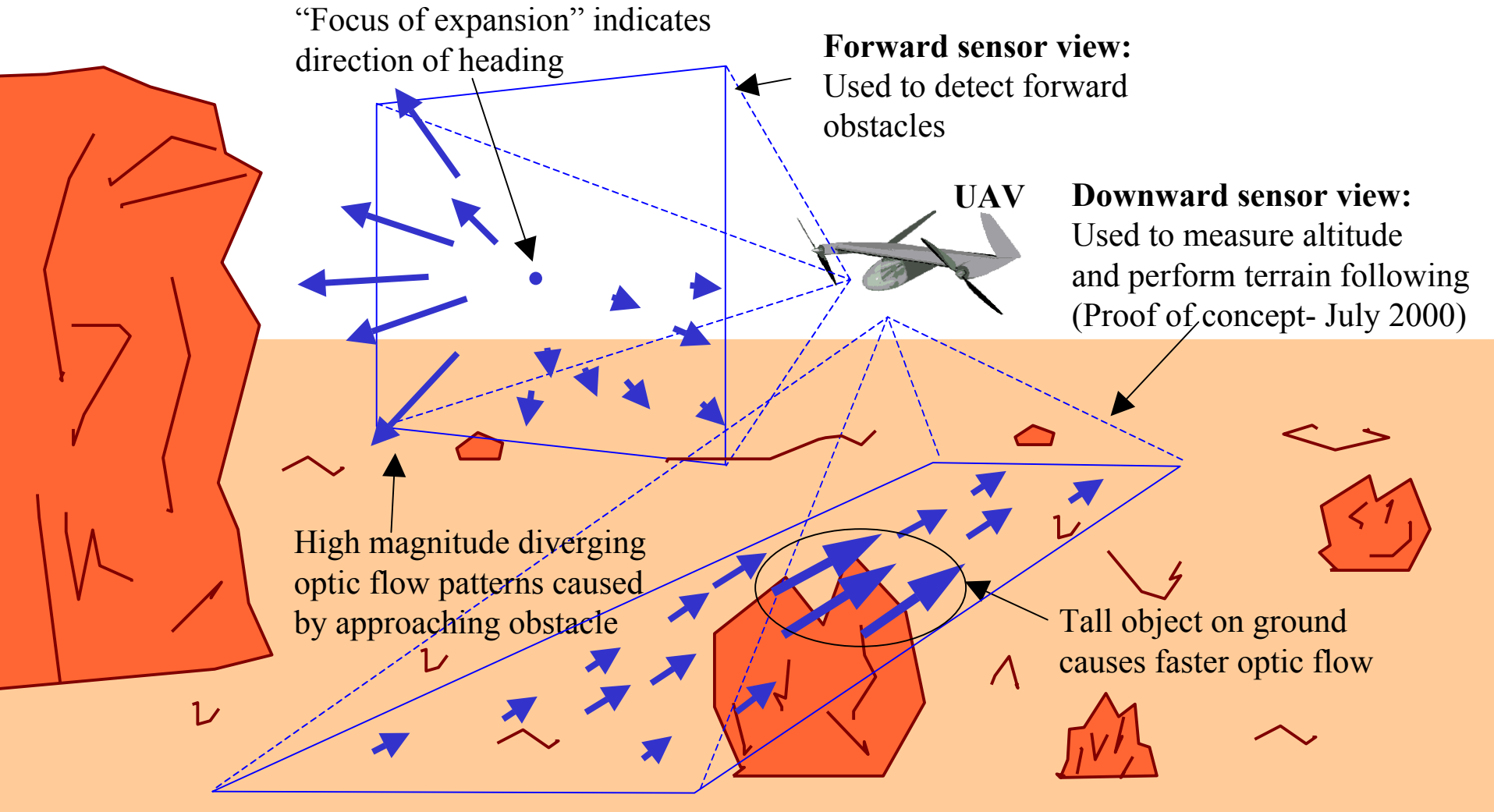
**Stereo Vision Chips:** Implements stereo matching algorithms to achieve depth perception from two images

**Centroid / Position Detector:** Determine X-Y location of bright or moving object on focal plane for tracking

**Position Sensor:** Determine location of an edge or predefined object

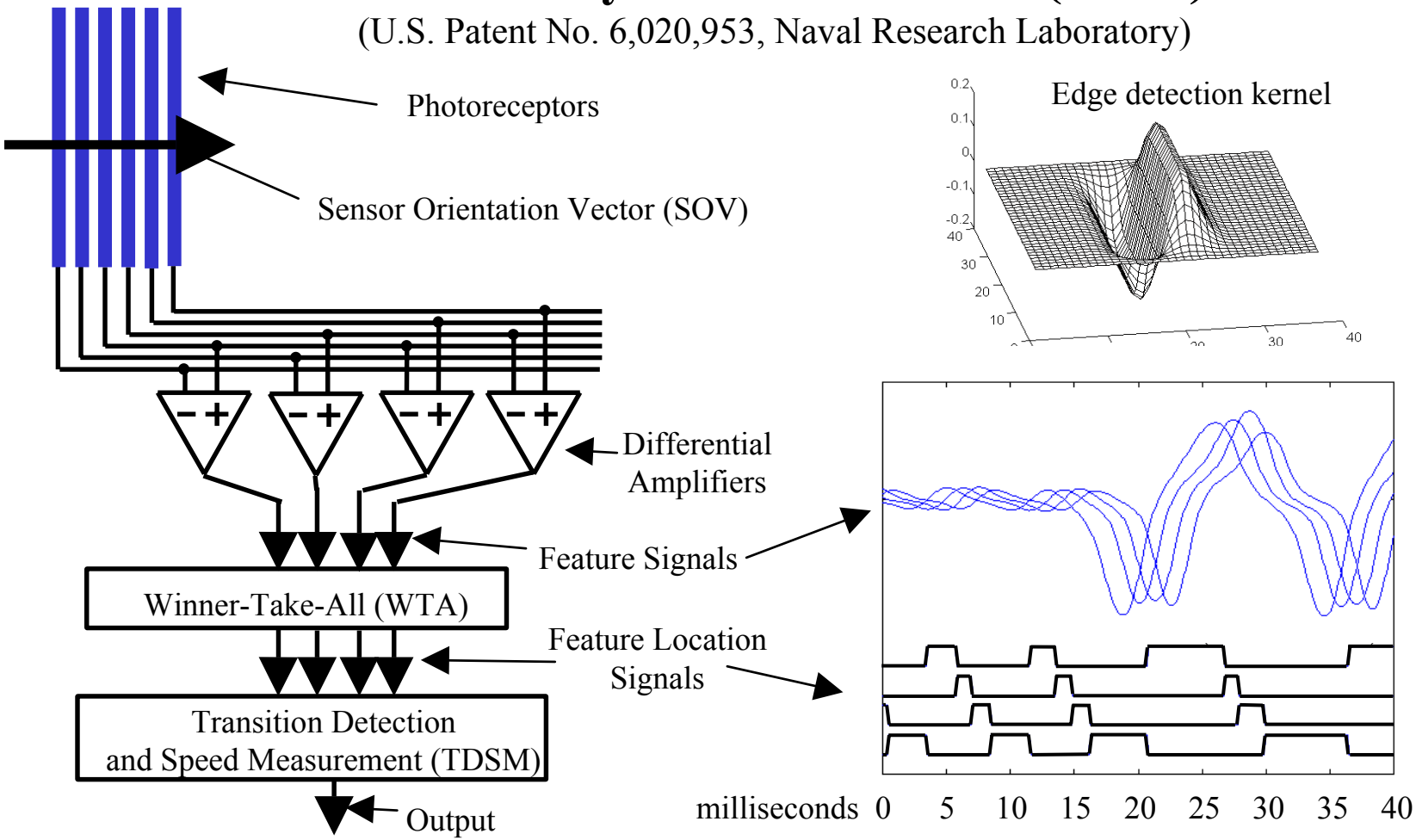
**"Neuromorphic Engineering":** Model biological vision systems in silicon

# Optic Flow for Altitude Control and Collision Avoidance



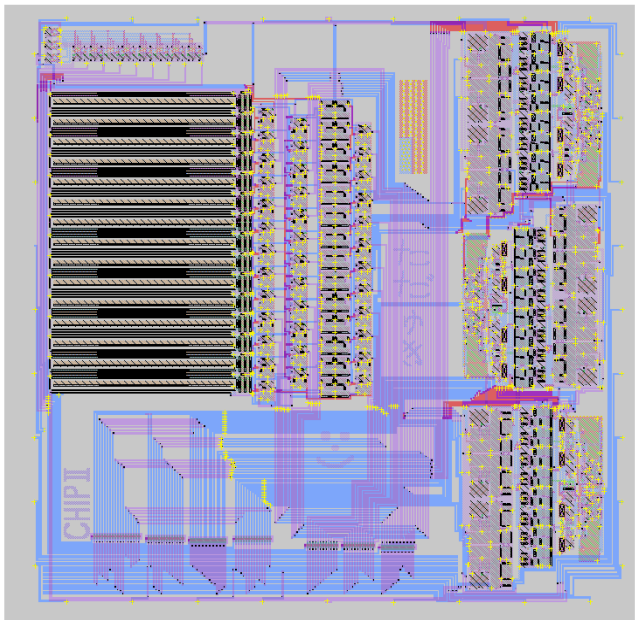
# Linear Competitive Feature Tracker (LCFT)
# Elementary Motion Detector (EMD)

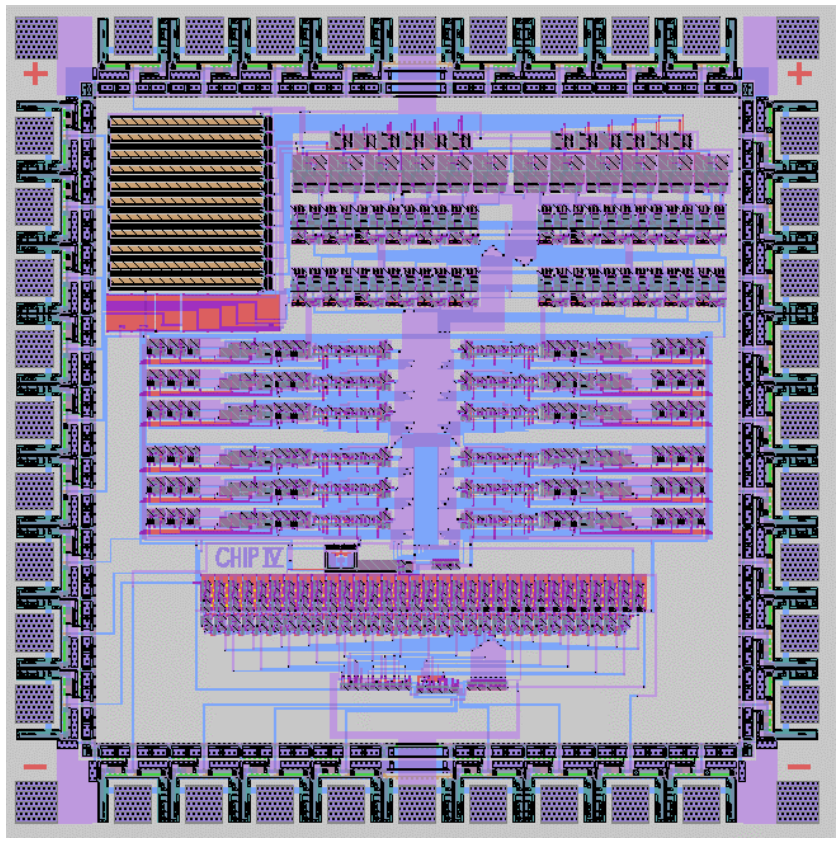
(U.S. Patent No. 6,020,953, Naval Research Laboratory)



# Fabricated Chips (AMI Inc. 1.2 micron process)

(Layout from Magic)

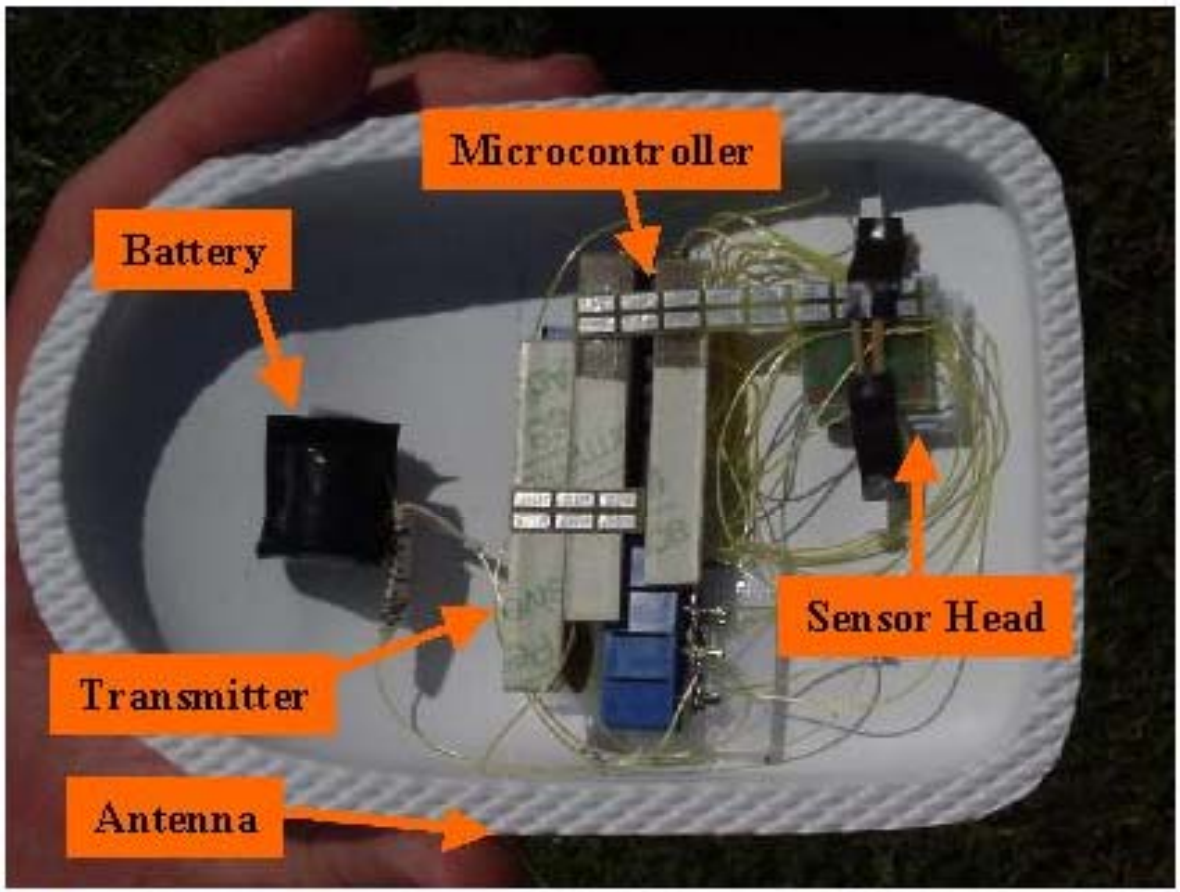



1998: Three CFT elementary motion detectors implemented in a 1.1 x 1.1 mm area

2000: Complete optic flow sensor chip implemented on a 1.9 x 1.9 mm chip

# Optic Flow Sensor for In-Flight Control of Aircraft Altitude (Summer 2000)




Credit: US Naval Research Laboratory

**Vision Chip (Sensor Head):**
Implemented photoreceptors, feature detectors, and WTA

**PIC 16C76 Microcontroller: (2kB PROM, 356B RAM, 1.2MIPS)**
Implemented remainder of CFT algorithm and fusion

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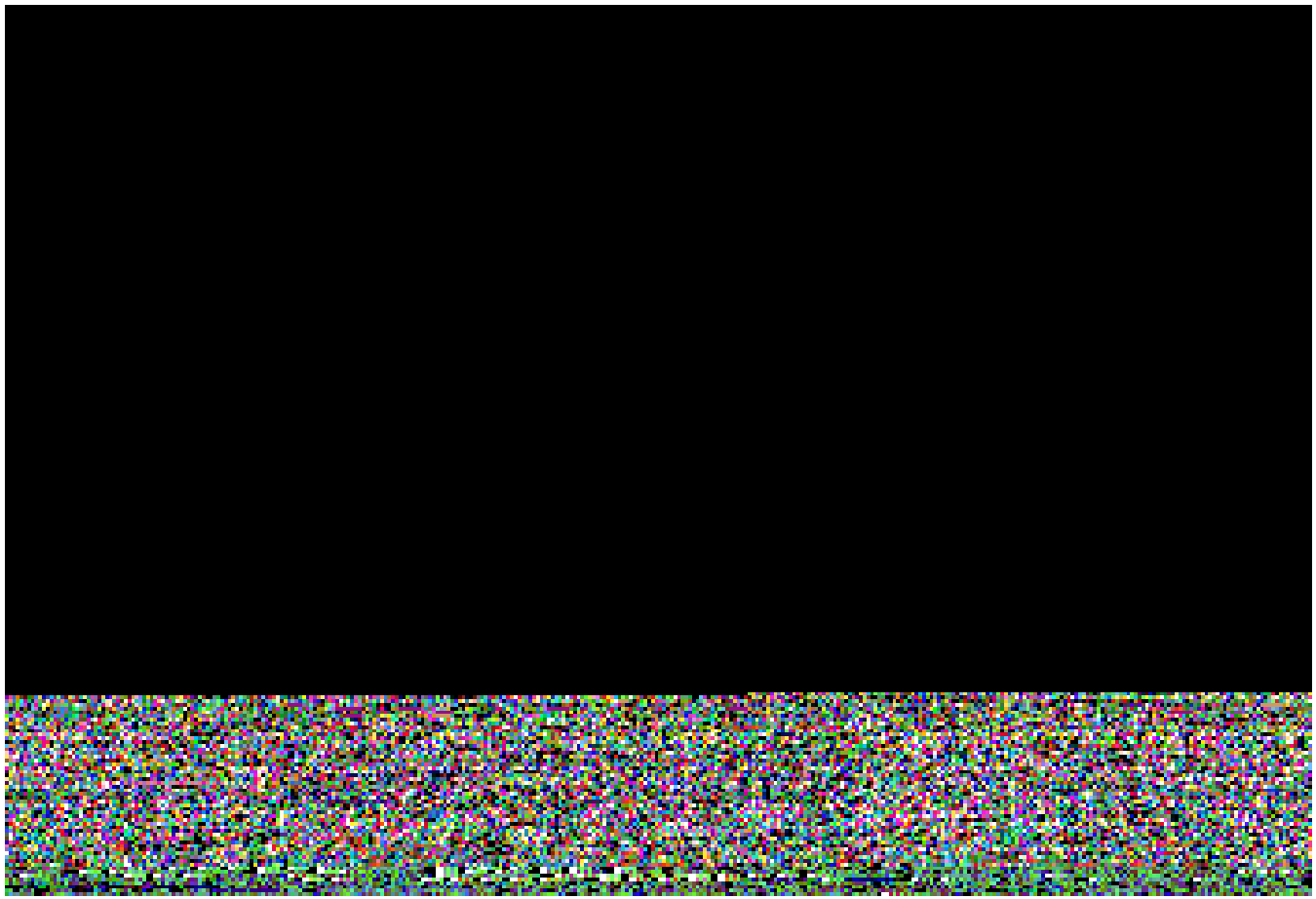

Credit: US Naval Research Laboratory

# Robotic Applications

The successful application will likely be that which the vision chip satisfies a **"sweet spot"** to make a proposed robot viable in the commercial or military marketplace.

**Uninhabited Air Vehicle (UAV) or Missile**

- **Altitude** and **collision avoidance**, when flying close to ground or among obstacles
- **Terrain following** for missile defense
- Sensor to guide **landing**
- Sensor to guide **docking** for refueling
- Image processor for **rapid target detection**

**Ground Robotics**

- General machine vision for **microrobotics (e.g. Tactical Mobile Robots)**
- Machine vision for **fast moving robots**
- **Ultra reliable** machine vision for macro robots (multiple redundant sensors)

**Industrial Automation and Process Control**

- **Position** Sensor

# Sensor for Motion Detection

- Sensor only responds to changes in light intensity
- Video clips show response of discrete-component model
- Sensor can be implemented to consume under 1µW

# Networked Array of Sensors

- Computing and sensing distributed across network
- Power requirements: Data transmission is more expensive than data processing
- Vision chips are ideal low-power smart-sensing devices

# Applications of Networked Array of Vision Chips

Surveillance and Security
- Intruder detection
- Crowd monitor

Intelligent Transportation Systems / Highways
- Traffic count and monitoring
- Pedestrian monitor

## Near-term Activities

Develop “field-programmable vision chip” incorporating various motion sensing algorithms on a single die

- Sub-assembly or vision chip alone
- Beta release expected in Winter 2002

Demonstrate improved terrain following and obstacle avoidance on small aircraft using optic flow sensors

# Conclusions

Vision chips are a new class of sensors that implement both image acquisition and image processing in one package

- Increased performance per weight, cost, or power consumption
- Can be an enabling technology for some image processing applications

Vision chip technology is beginning to find application in solving practical problems

- Some instances of vision chips solving practical problems
- Some instances of vision chips becoming viable commercial products

Vision chips are candidate technology for providing sensing capabilities to a network